ngDIFMAP: new generation DIFMAP and applications in AGN morphology

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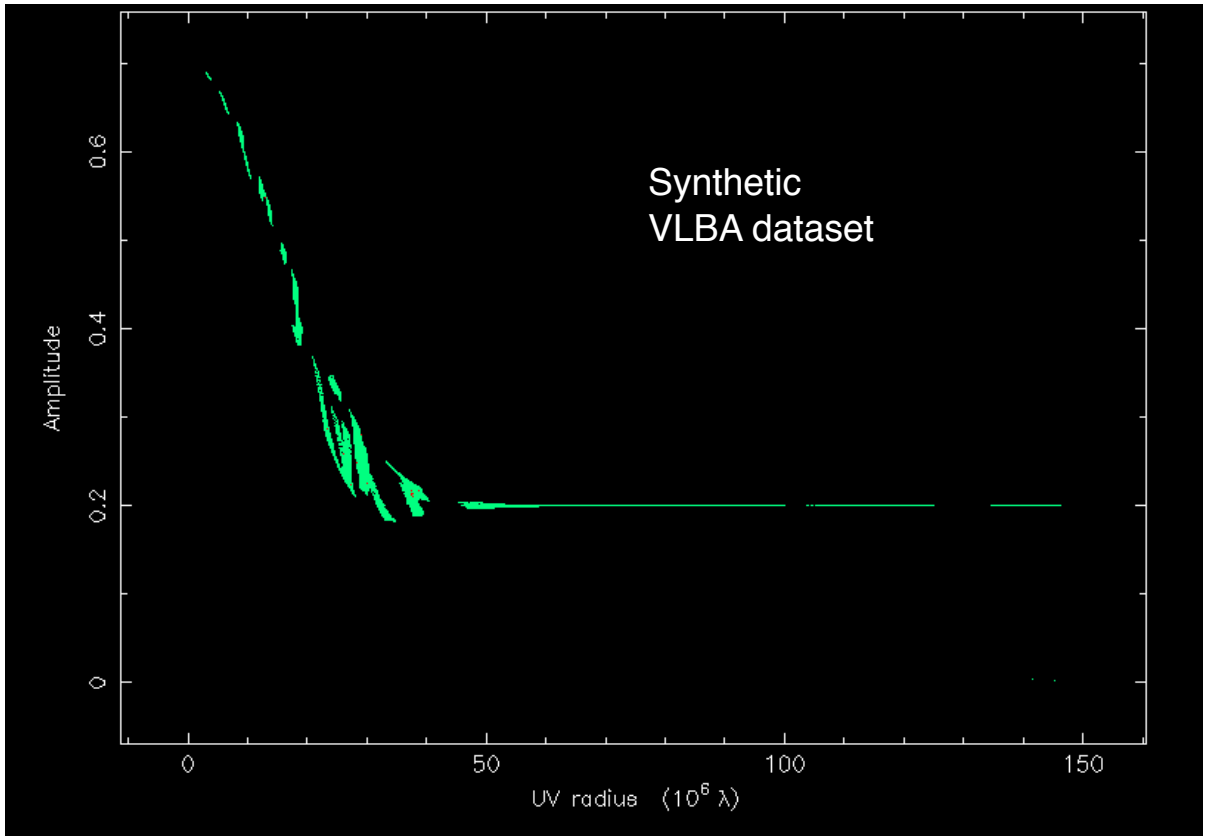
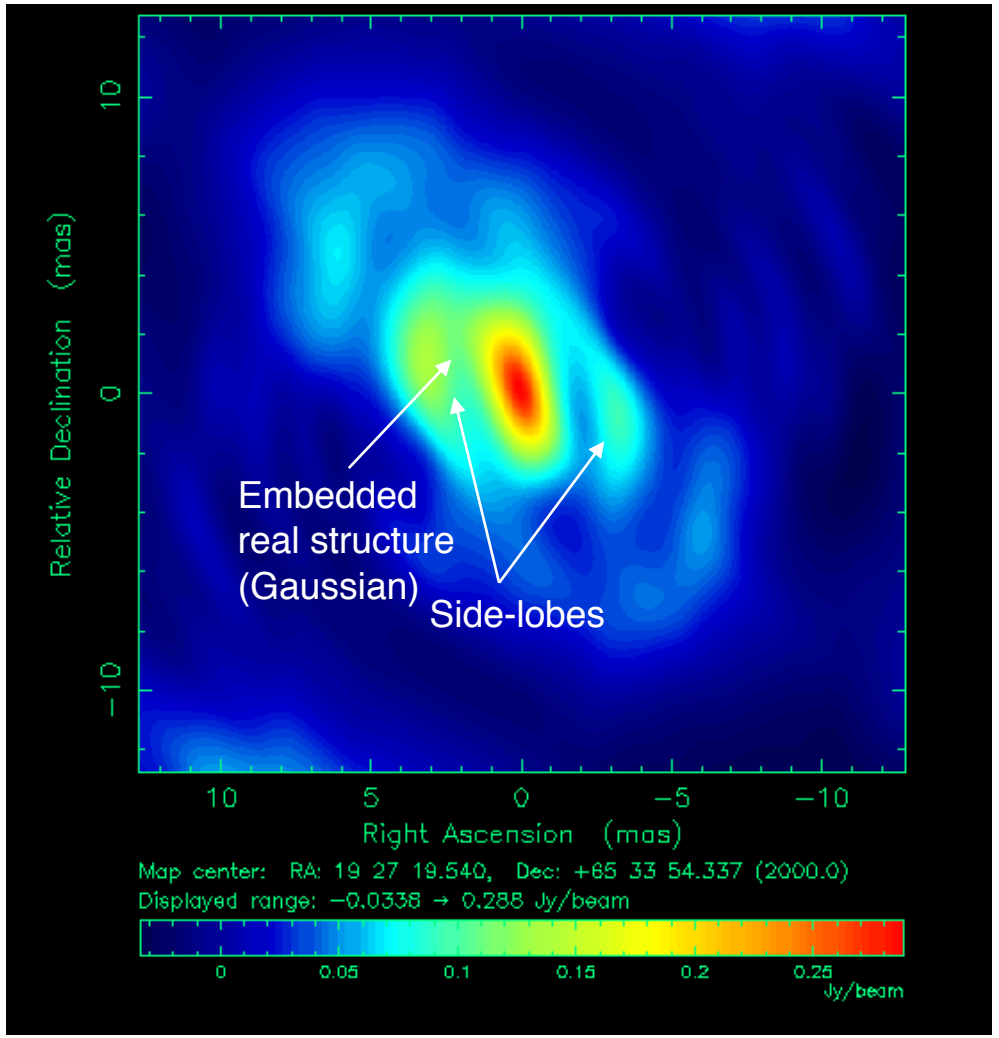
Why DIFMAP (Shepherd M., Pearson T., Taylor G., 1994) :

Sparse U-V coverage





Why DIFMAP :

Interferometric gain errors

Antenna-specific gain

True visibility

Baseline-specific gain

Thermal noise

$$\tilde{V}_{ij} = H_{ij} G_i G_j^* [V_{ij} + \epsilon_{ij}]$$

Antenna-separable errors

$$\tilde{V}_{ij} = (1 + a_i)(1 + a_j) e^{i(\phi_i - \phi_j)} A_{ij} e^{i\Psi_{ij}} +$$

$$\tilde{\Psi}_{ijk}(t) = [\tilde{\Psi}_{ij} + \tilde{\Psi}_{jk} + \tilde{\Psi}_{ki}] = [\Psi_{ij} + \Psi_{jk} + \Psi_{ki}] +$$

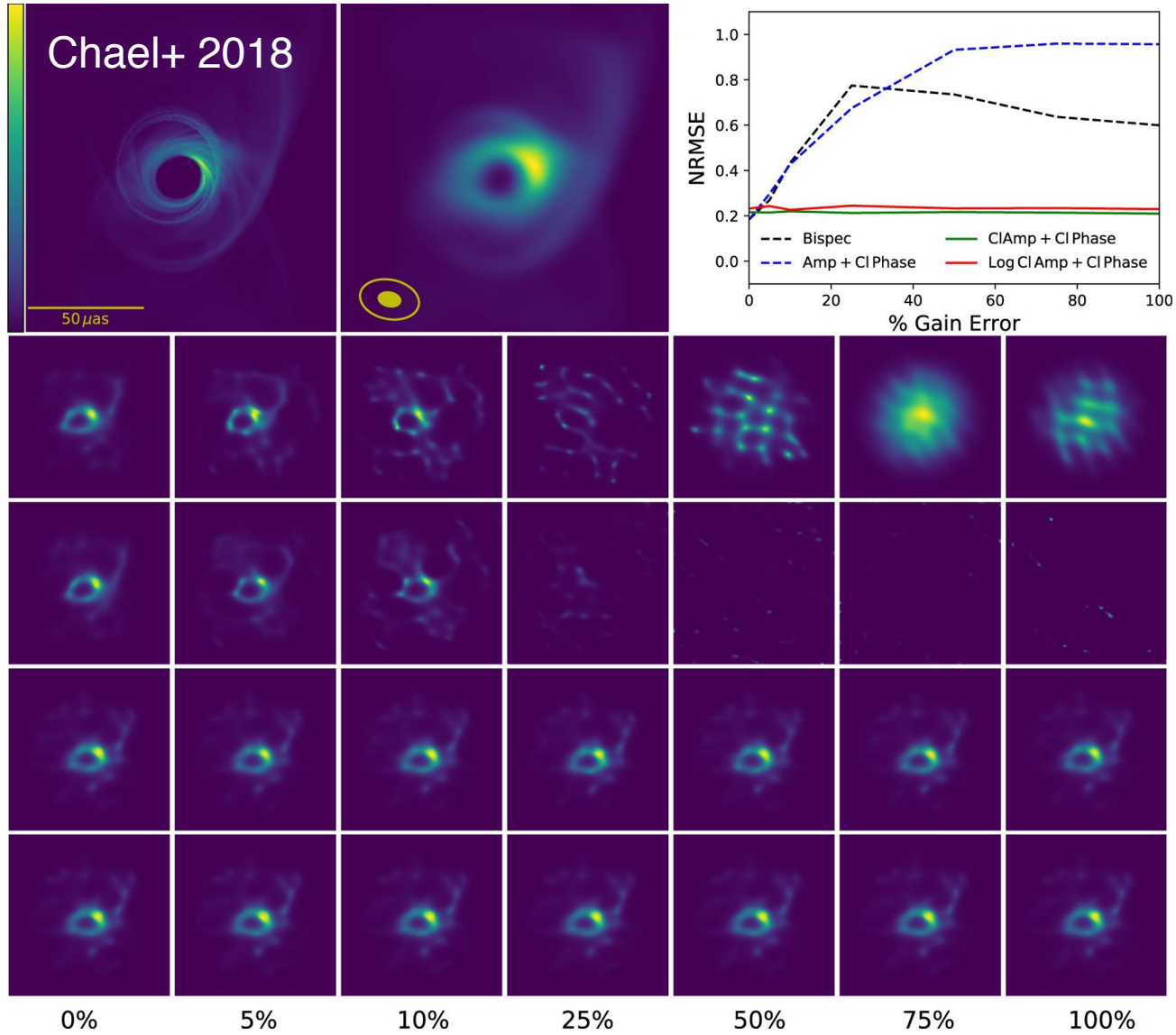
Closure phase

$$A_{ijkl} = \frac{|\tilde{V}_{ij}||\tilde{V}_{kl}|}{|\tilde{V}_{ik}||\tilde{V}_{jl}|} = \frac{|V_{ij}||V_{kl}|}{|V_{ik}||V_{jl}|}$$

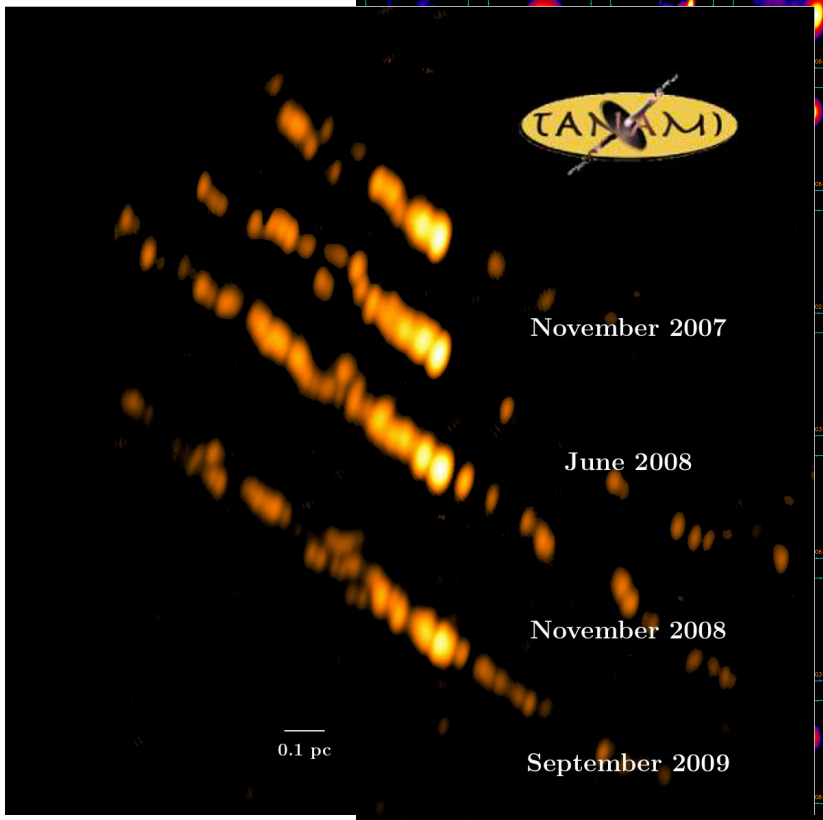
Closure amplitude

Baseline-based, or “closure” errors (figure)

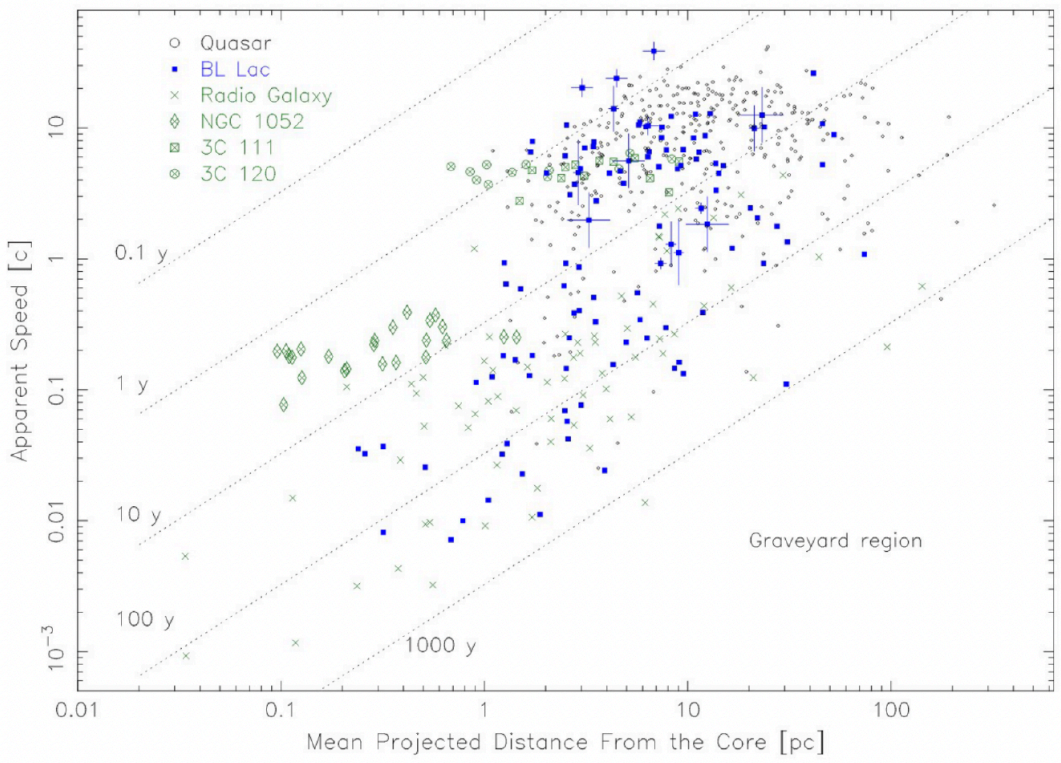
$$\tilde{V}_{ij} = [1 + Y_{ij}(t)] e^{j\delta\phi_{ij}} [V_{ij} +$$



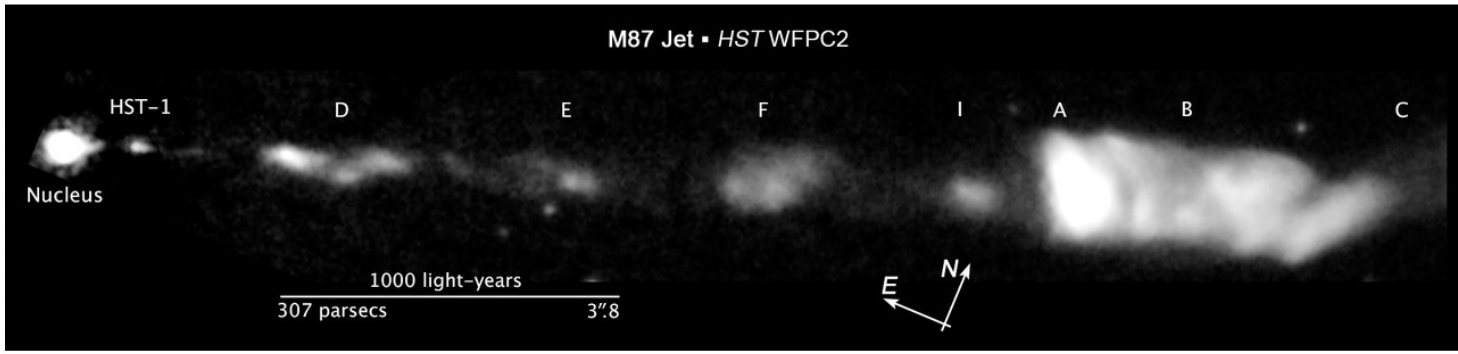
DIFMAP and jet kinematics

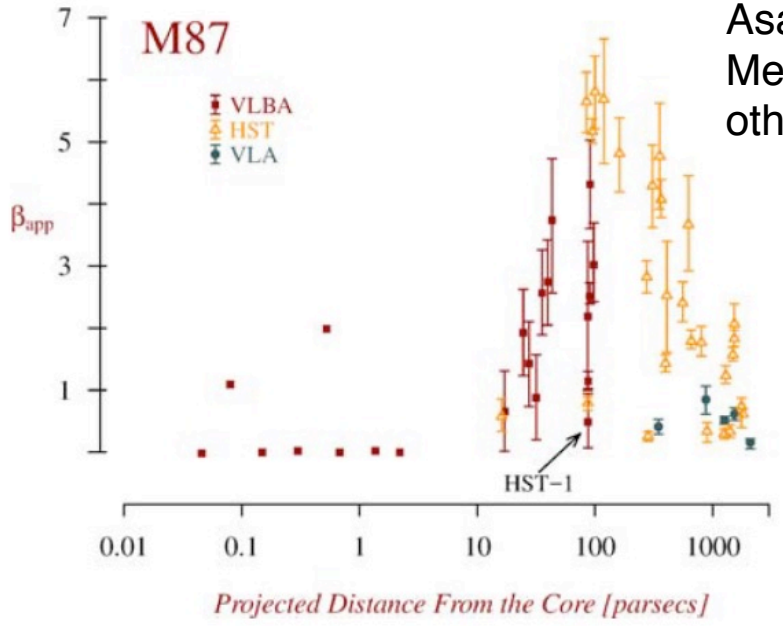


A “MOJAVE on the kpc-scale”?

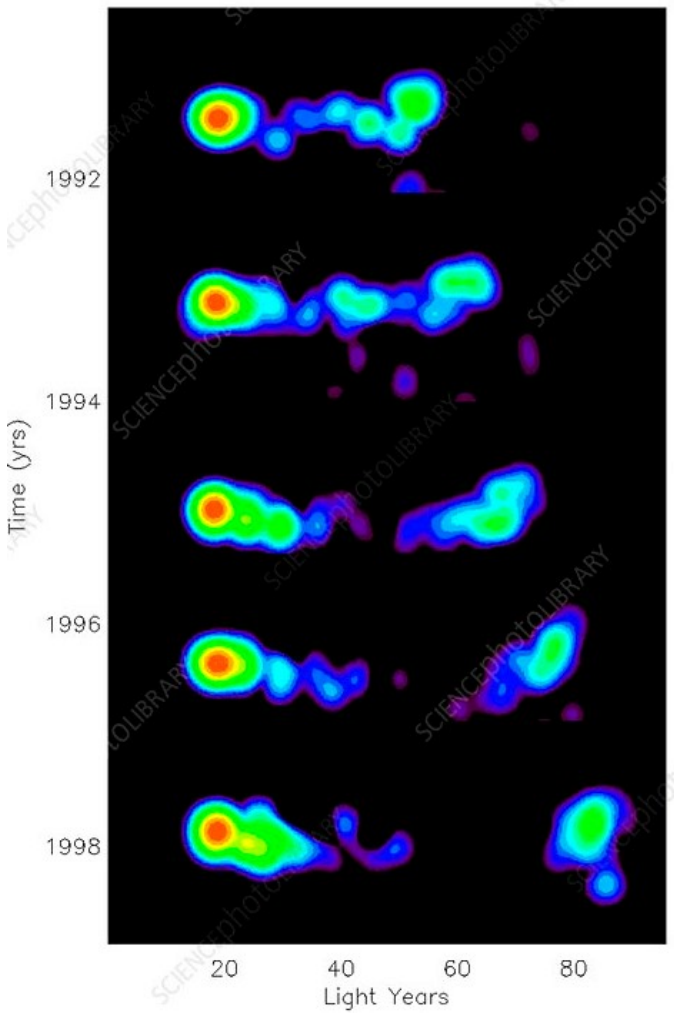


Lister+ 2016

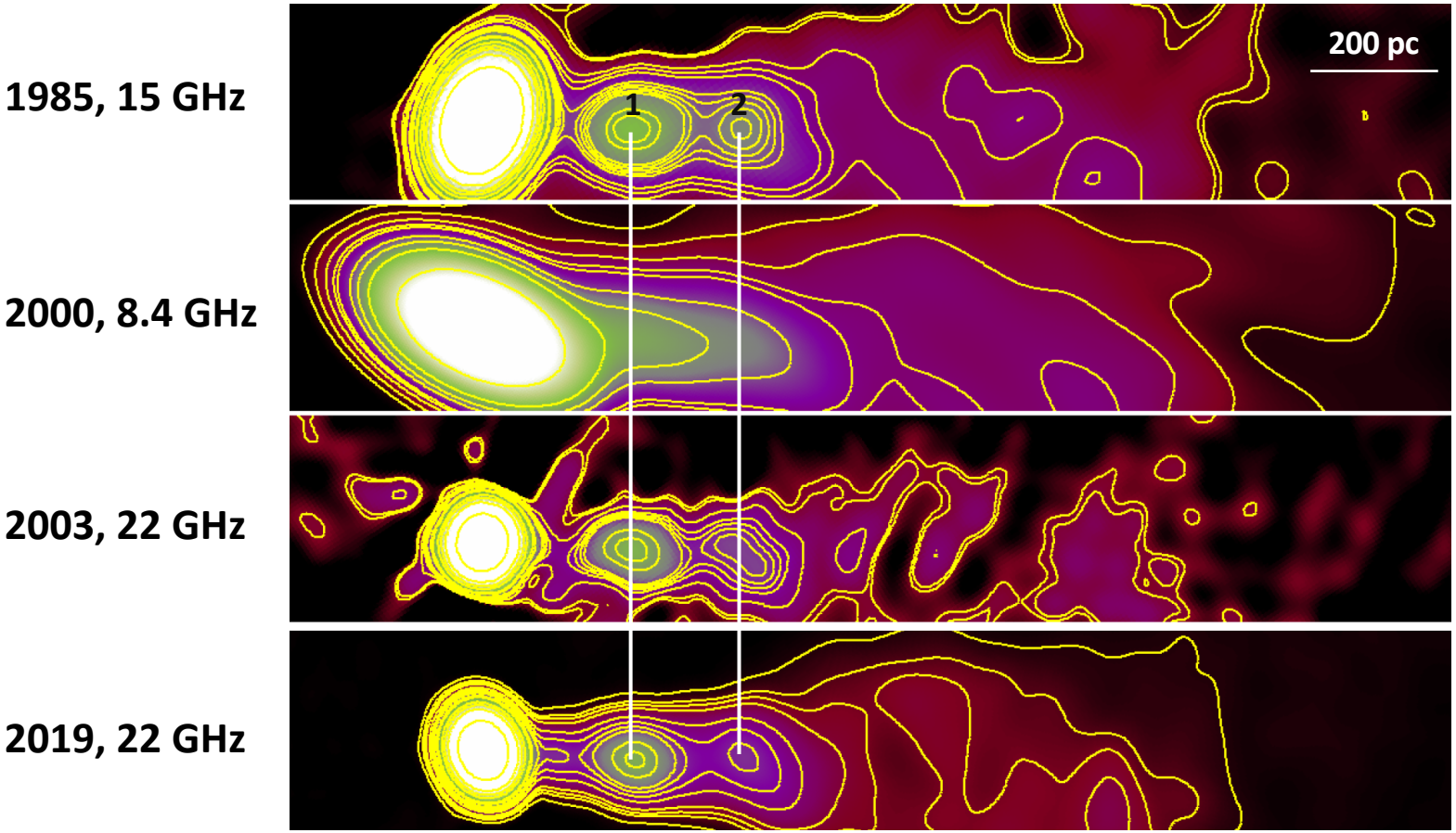




Asada+ 2014, Meyer+ 2015 and others



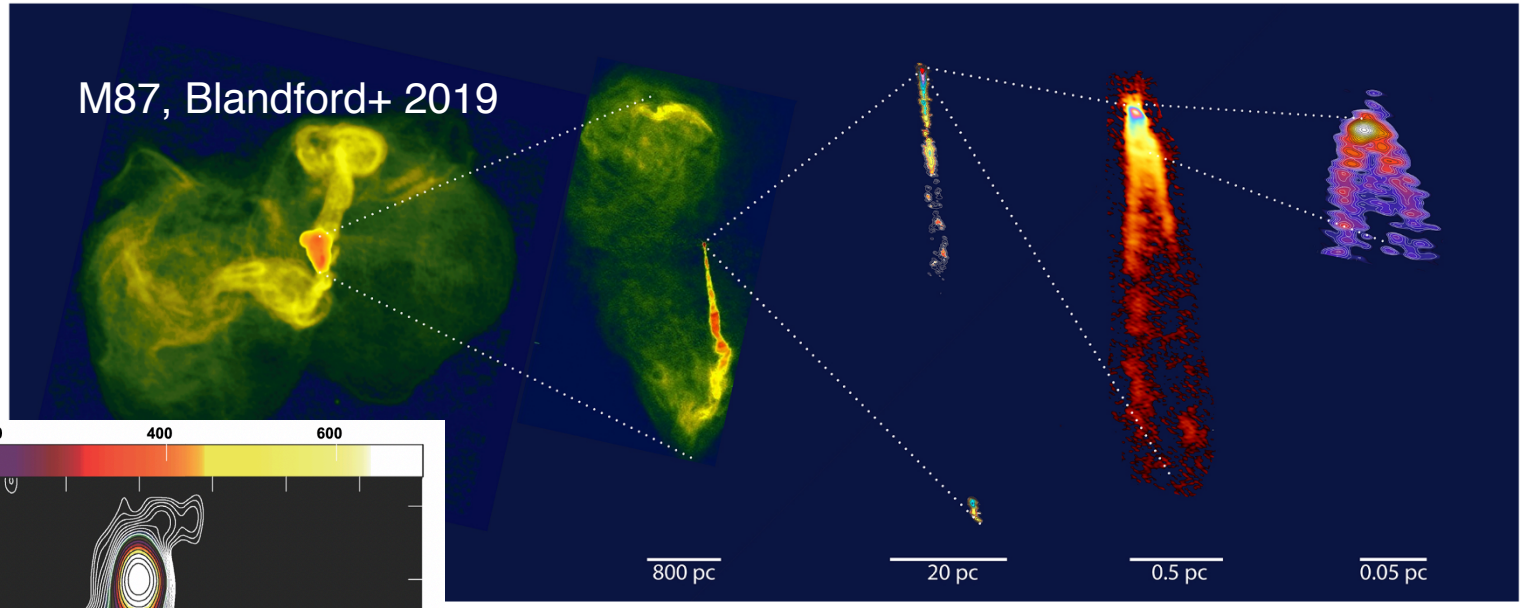
VLBI Jet of 3C 279
(Wehrle+ 2001)

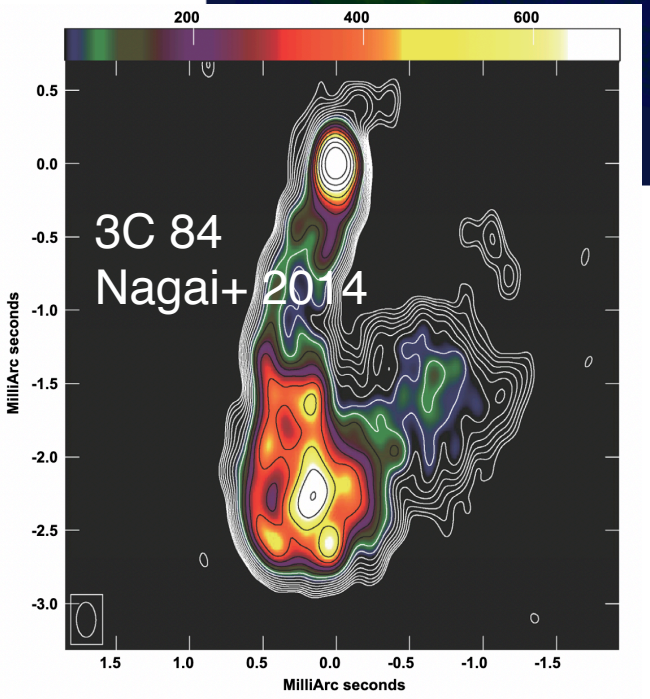


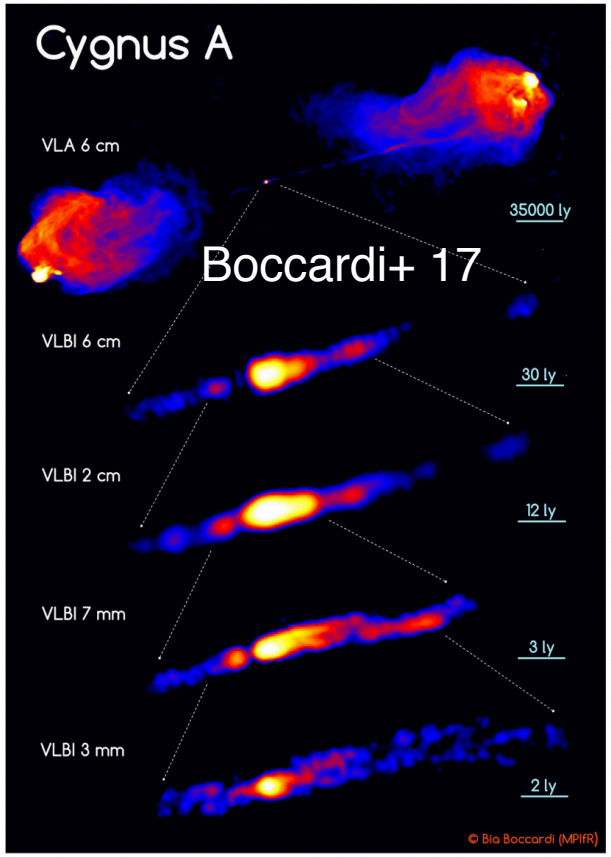
VLA jet of 3C 78

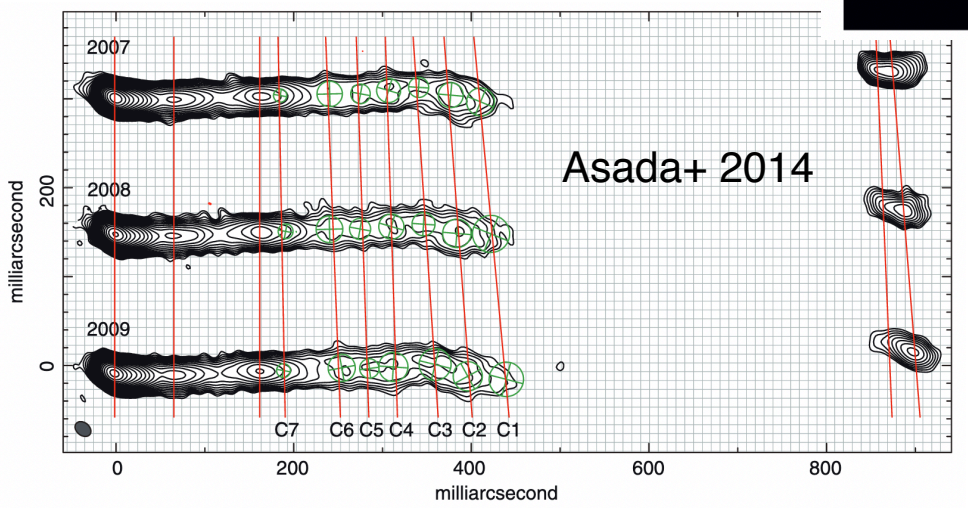
Need higher accuracy, and uncertainties need to be quantified.

Need for model complexity:

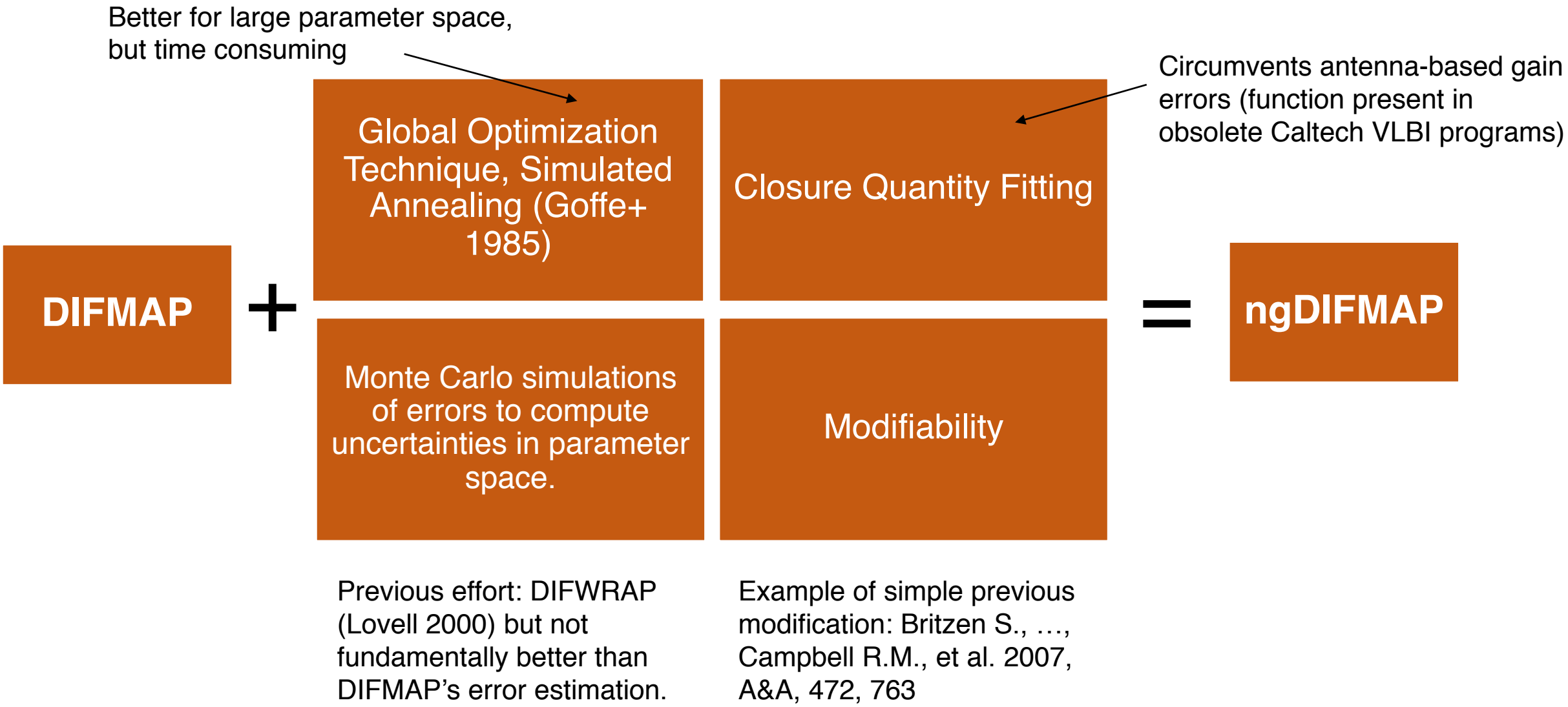






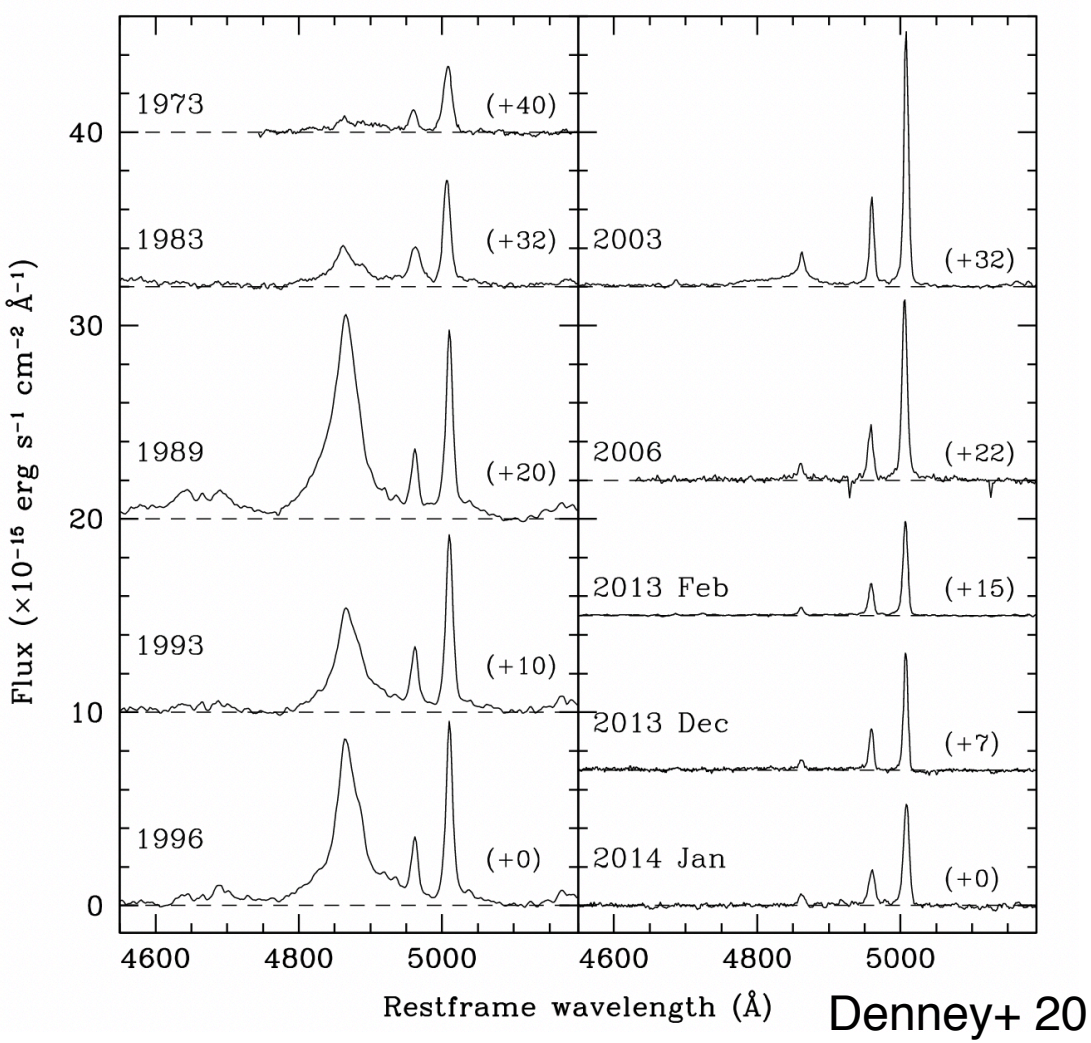


Introducing ngDIFMAP and capabilities

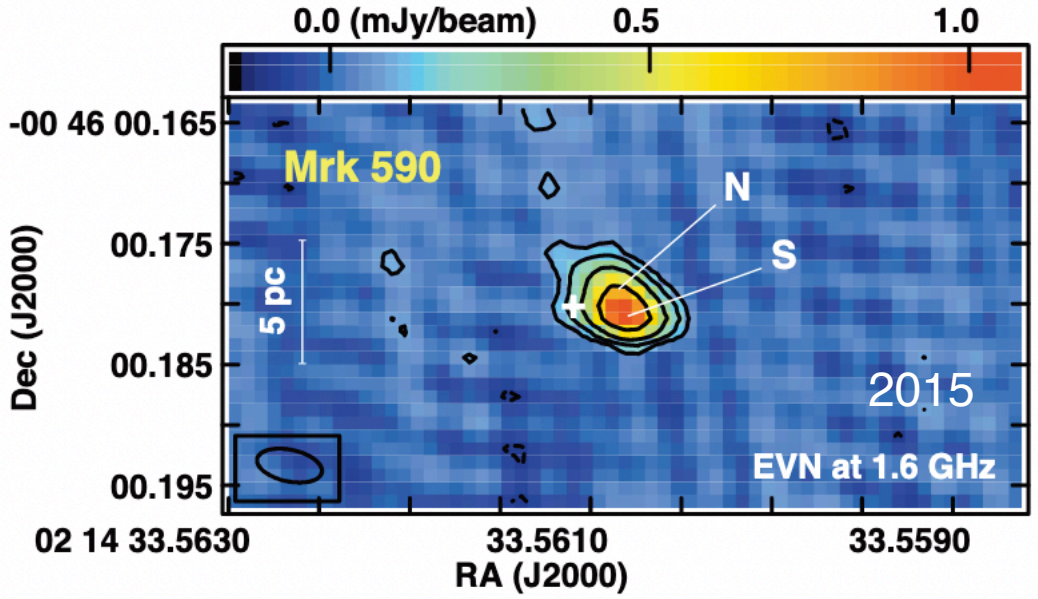


Application (DIFMAP)

Radio emission from radio-quiet AGN: case of changing look Mrk 590



Denney+ 2014

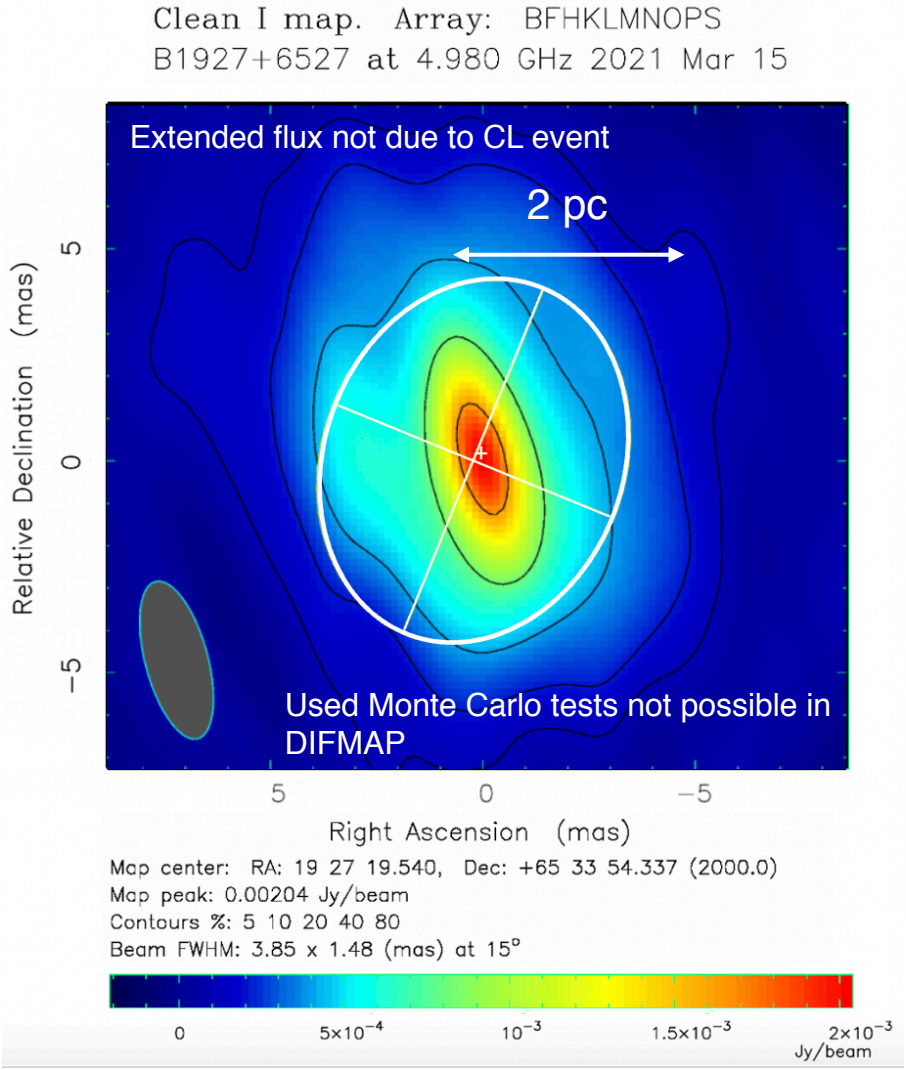


Possible nascent jet, Yang+ 2021

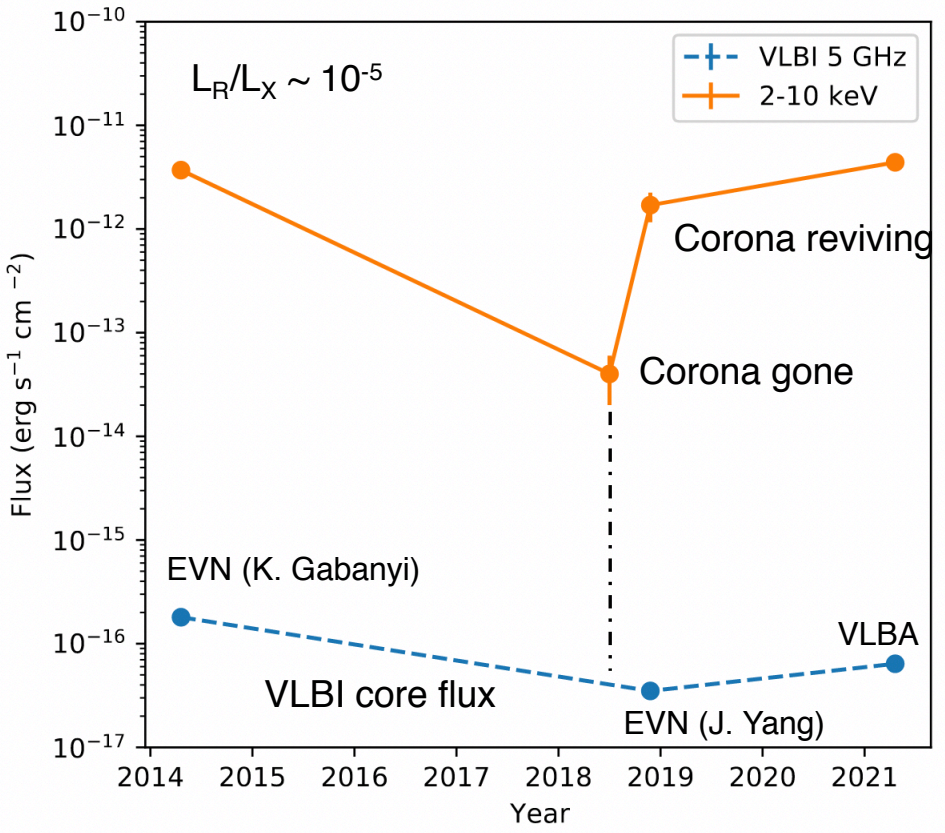
Software used: AIPS+DIFMAP

Application (ngDIFMAP)

Radio emission from radio-quiet AGN: case of changing look 1ES 1927+654



Appearance of broad lines around 2017-2018

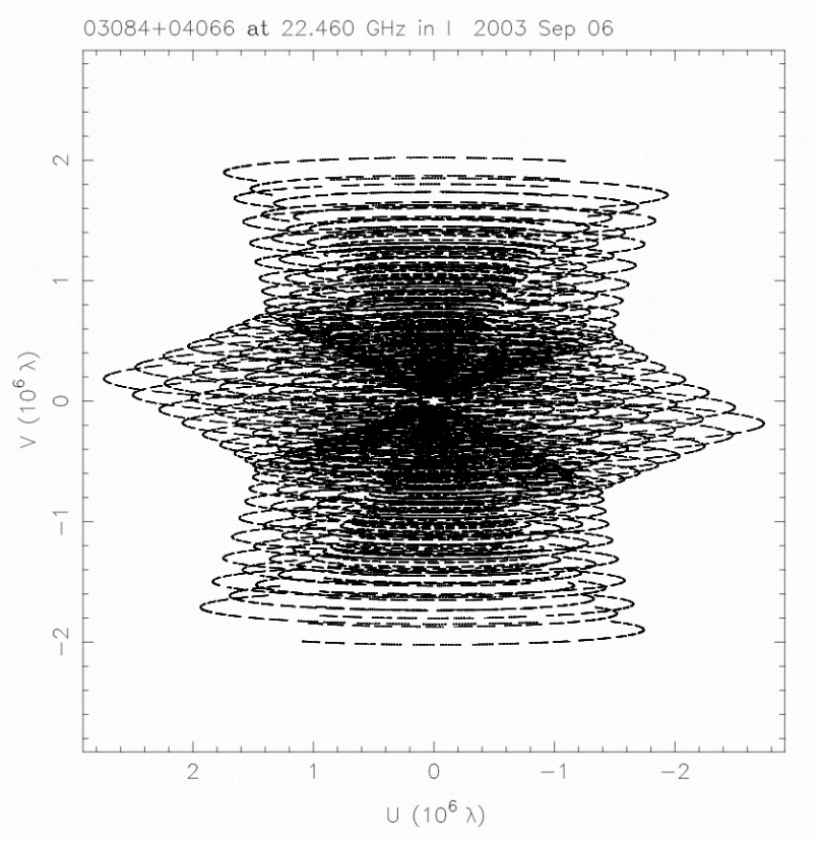


Near confirmation of coronal origin of radio emission (synchrotron). Has *never* been observed before.

arXiv: 2203.07446, Laha+, 2022, ApJ, 931,5

Software used: AIPS+**ngDIFMAP**

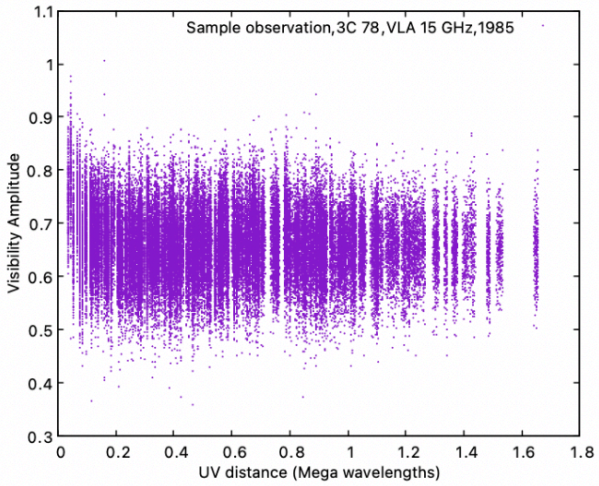
Determination of uncertainties in model-fitting

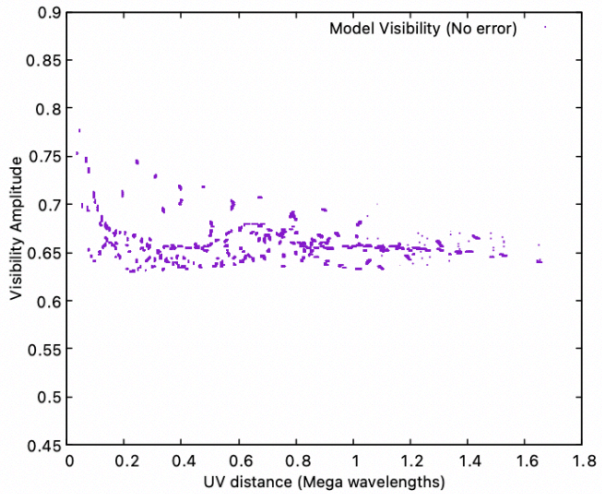


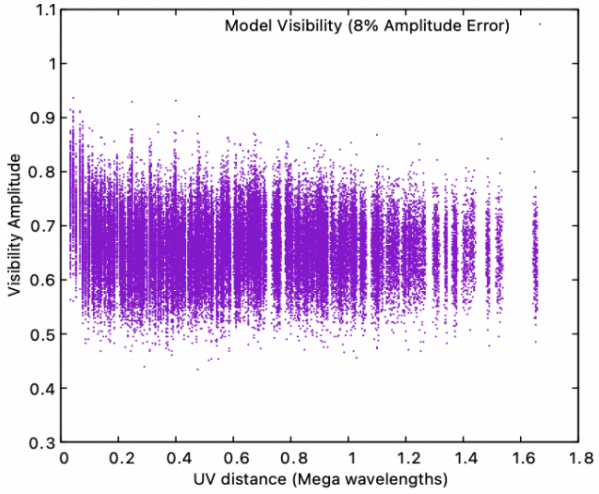
$$\tilde{V}_{ij} = [1 + Y_{ij}(t)]e^{j\delta\phi_{ij}}[V_{ij} + \epsilon_{ij}(t)]$$

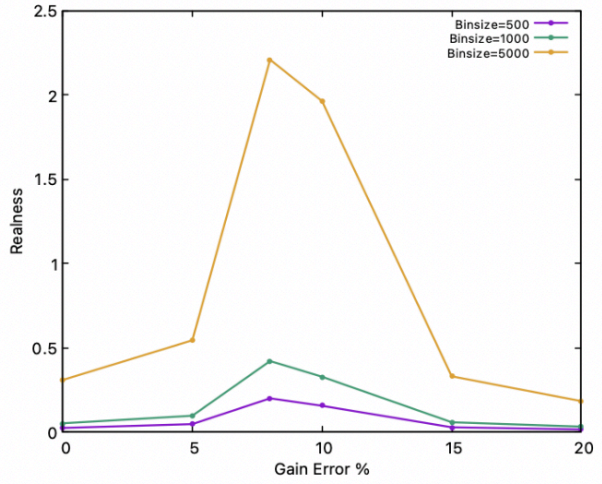
$$Y_{ij} \sim \mathcal{N}(0, \sigma_g) \qquad \delta\phi_{ij} \sim \mathcal{N}(0, \sigma_p)$$

Starting best-fit model → Random loss in UV coverage and residual gain errors (Monte Carlo method) → Resulting parameter covariance matrix from *all* best-fit results, not single-fit matrix already in DIFMAP

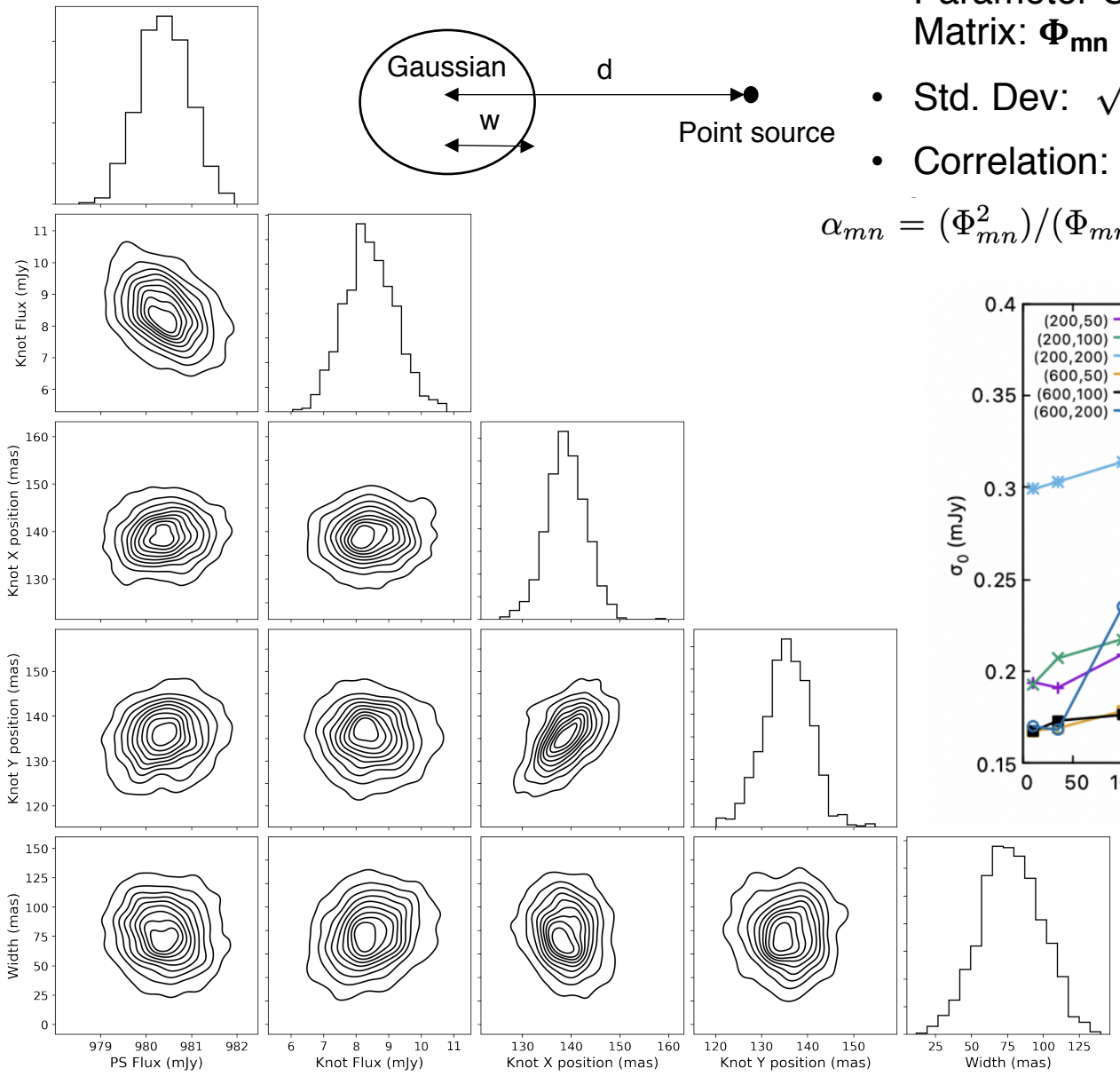






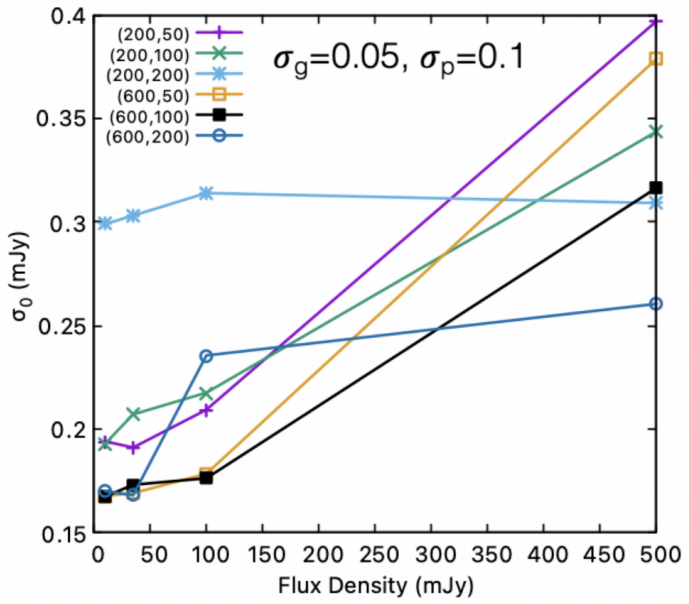


Starting test model and output plots:

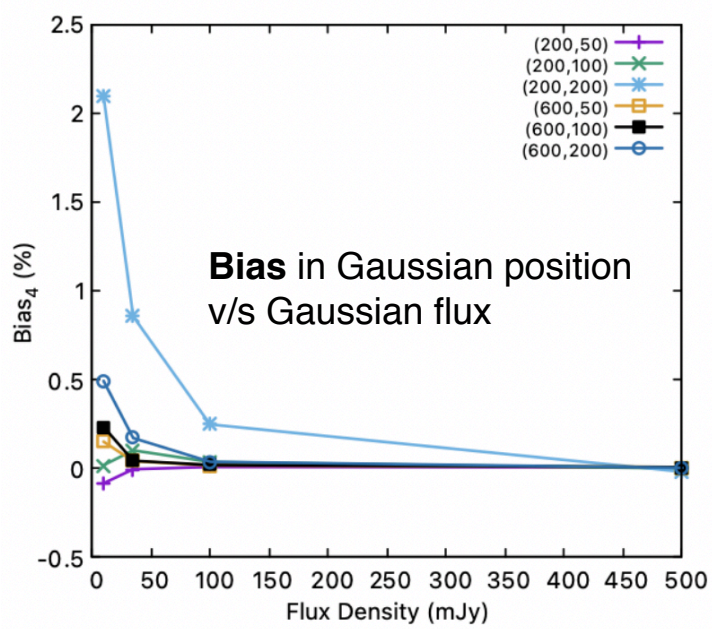


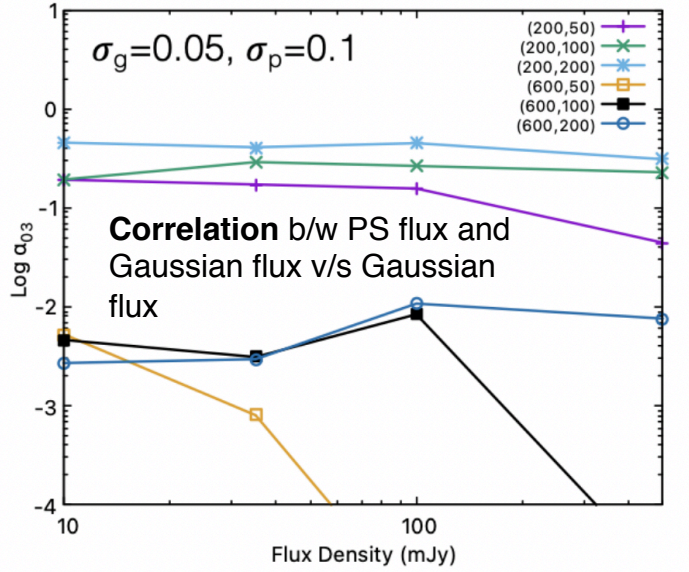
- Parameter Covariance Matrix: $\mathbf{\Phi_{mn}}$
- Std. Dev: $\sqrt{\Phi_{mm}}$
- Correlation:

$$\alpha_{mn} = (\Phi^2_{mn})/(\Phi_{mm}\Phi_{nn}) \in (0,1)$$



Point source flux **std. dev.** v/s Gaussian flux





Roychowdhury+ 2022a (to be submitted)

d=200, w=200, F=10 mJy, $\beta\lambda = 0.1$, $\sigma_g = 0.15$ and $\sigma_p = 0.2$

Summary and conclusions

- Novel modification to DIFMAP to robustly understand noisy interferometric data.
- New models will be added and convolution engine will be improved (only Gaussians and PSs can be convolved in DIFMAP).
- Immense scope for further modification: possibilities include *rewriting* DIFMAP with MPI to handle latest large datasets.

Originally developed for CAgNVAS: *Catalogue of proper motions in extragalactic jets from Active galactic Nuclei with Very large Array Studies*.
(Vide talk at COSPAR (E1.2) next week.)